Food and Agriculture Organization of the United Nations

World Health Organization

JOINT FAO/WHO EXPERT MEETING ON HAZARDS ASSOCIATED WITH ANIMAL FEED

12 – 15 May 2015
FAO Headquarters, Rome, Italy

EXECUTIVE SUMMARY OF THE REPORT

The expert meeting was jointly organized by the Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), in line with their overall aims of securing feed and food safety and ensuring fair practices in the trade of feed and food. The objective of the meeting was to provide an updated overview of the current state of knowledge on hazards associated with feed (including feed and feed production technologies of increasing relevance, such as insects, former food and food processing by-products and biofuel by-products). The meeting was also intended to provide guidance on the most appropriate use of this information for risk analyses purposes; to identify knowledge gaps and to prioritize future work on the identification of potential hazards of key global concern from the perspective of human and animal health.

The need for feed for terrestrial and aquatic animals continues to rise with the increasing demand for foods of animal origin; however, the challenge is not only to meet this growing need for feed but also to ensure its safety. Feed safety incorporates the impact on human as well as animal health and welfare, which, in turn, can affect productivity. Hazards in feed may be inherent to feed ingredients as well as introduced during feed production, processing, handling, storage, transportation, and use. Hazards may also result from accidental or deliberate human intervention.

This report considers hazards in animal feed which present a risk for human health as a result of transfer from feed to foods of animal origin. It also addresses the impact of these hazards on animal health. While acknowledging the potential wider impacts of some of these hazards on animal health, welfare and productivity, and in turn on food security, the meeting did not comprehensively address these aspects but noted the need for further work in these areas. Hazards in water were considered wherever relevant in accordance with the Codex definition of animal feed1. With regard to specific issues, veterinary drugs intentionally added to feed were not considered within the scope of the meeting. Antimicrobial resistance was not considered by the expert meeting as it is currently being addressed more comprehensively in other fora.

The expert meeting reviewed and discussed potential hazards in feed of chemical, biological and physical origin. While reviewing a wide range of hazards it did not prioritize any particular one or any group of hazards, because of differences in their potential presence in feed according to geographical area, production system and kind of feed (e.g. compound feed vs. pasture or forage), among others. The chemical hazards considered included persistent organic pollutants (POPs) such as polychlorinated dibenzo-dioxins (PCDDs) and polychlorinated dibenzo-furans (PCDFs), dioxin-like polychlorinated biphenyls (dl-PCBs) and non-dioxin-like polychlorinated biphenyls (ndl-PCBs); veterinary drug residues; organochlorine and other pesticides; potentially toxic elements (PTEs) (e.g. arsenic, cadmium, lead, mercury); mycotoxins; and plant toxins (e.g. genotoxic pyrrolizidine alkaloids and anti-nutritionals such as glucosinolates) as well as other potential and emerging chemical hazards. The review of biological hazards considered primarily bacteria but also parasites, viruses and prions. In terms of physical hazards, radionuclides, residues of nanomaterials, micro- and nano-plastics and other relevant materials were addressed. For each of the above, the hazard as well as its occurrence in feed was described, and transfer from feed to food, relevance for food safety, impact on animal heath, and emerging issues and trends were reviewed. In addition, specific consideration was given to feed and feed production technologies of increasing relevance. Specific hazards and research requirements associated with the use of insects, former food and food processing by-products, biofuels (bioethanol and biodiesel) by-products, aquatic plants and marine resources as feed were highlighted. Methods of analysis, including multi-an-

1 Feed (Feedingstuff): Any single or multiple materials, whether processed, semi-processed or raw, which is intended to be fed directly to food producing animals. (CAC/RCP54-2004)

alyte methods, and sampling were also addressed and for each of the potential hazards both screening and confirmatory methods were considered.

OVERVIEW OF FINDINGS

This expert meeting considered the following information, which formed the basis for its conclusions and recommendations: (i) publicly available literature summarized in the background paper as well as additional inputs and information provided through its peer and stakeholder review, (ii) data and information provided through a call for data, and (iii) information and expertise provided by the individual experts, and resource people present at the meeting.

Highlighting that hazards in feed may present an important risk for human health as a result of transfer from feed to food of animal origin, and can have a negative impact on animal health and welfare, the meeting stressed the importance of pursuing the prevention and control of hazards in animal feed. Standards, guidelines and practical measures to ensure safe feed need to be developed and implemented, at both national and international levels. Action from multiple players is required to build upon what has already been done to address feed safety by Codex, FAO, WHO and other organizations, national regulators and the feed industry. Ongoing and enhanced capacity development is an important aspect of improving feed safety, particularly in the context of changing feed production systems and feed sources, the need for sustainability in animal production systems and the broader context of global food security.

The expert meeting highlighted the role of risk assessment as well as the numerous challenges in undertaking risk assessment presented by the wide range of hazards and feed sources, including the need to generate the necessary data on some of these contaminants, collate those data, if feasible through a global platform and where necessary develop the methodologies needed to facilitate such risk assessment. For example, sampling approaches and sampling plans were identified as a key area to be addressed in terms of data collection and monitoring of hazards in animal feed. The role of the industry in generating data to facilitate risk assessment as well as that of national authorities and international bodies to ensure that such data are generated was emphasized.

While not explicitly addressed, the expert meeting was keen to emphasize that the value of available data and risk assessment is only realized when subsequent risk management measures are identified and implemented and noted that the information provided in this report serves as a starting point in focusing risk management action.

Noting the recognition that Codex Alimentarius gives to safe feed for the production of safe food, the meeting concluded that in order to provide countries with the tools they need to manage feed safety, there was now a need for Codex to continue including explicit consideration of feed when developing or revising Codex standards, codes of practice and other relevant texts for biological and chemical contaminants. The meeting also recognized the differences that exist between countries in relation to their regulatory frameworks for feed, in particular between high-, middle- and low-income countries, and the impact this can have on the potential to manage such hazards. This may be a particular issue in many low-income countries where legislation and infrastructure for the management of feed safety is still immature or even non-existent. The ongoing development of new technologies to make use of available potential feed sources in the context of increasing demand for foods of animal origin highlights the importance of having capacity to address, not only the assessment aspects, but also drive the development of institutional frameworks. While regulatory aspects could not be addressed within this meeting they were highlighted as important issues to be considered by feed regulatory fora.

The meeting did not attempt to prioritize the hazards that were reviewed as it concluded that this should be undertaken on a country by country basis taking into consideration the specific situation, including feed sources and production systems and the guidance on prioritization of hazards in feed developed by Codex Alimentarius[2]. While that guidance already indicates a number of factors that need to be considered in the prioritization process, the meeting underlined food security as an additional criterion to consider. Overall however, the meeting highlighted that in the changing environment in which feed is now being produced and used, whether it be changes in climate, farming practices or the increasing use of different feed sources and feed production technologies, there is a need to regularly review the potential hazards from these feed sources, to be aware of the potential for new hazards to emerge and be ready to take the necessary steps to manage these.

2 Codex Guidance to governments on prioritizing hazards in feed (CAC/GL 31-2013) Available at http://www.codexalimentarius.org/input/download/standards/13312/CXG_081e.pdf

While genetically modified organisms (GMOs) were addressed in the meeting, given the increasing adoption of this technology in crops used as feed worldwide over the last two decades, it was also considered that the products of GMOs are not hazards as such as each one should be subject to an assessment for safety prior to use in line with Codex Guidelines for the Conduct of Food Safety Assessment of Foods Derived From Recombinant DNA Plants[3].

Finally, the meeting recognized the breath of information on analytical methods for detection of hazards and the challenges it presents for countries in terms of both accessing that knowledge and understanding what is relevant for animal feed. For example, many of the existing methods for hazard detection have not been validated for all relevant feed and feed ingredients while no reliable methods are available for a number of the identified hazards. In this context, the expert meeting developed a table of information to provide users with an overview of the methods available specifically for hazards in feed and the scope of their application, which serves as a unique reference point for such information.

OVERVIEW OF SOME OF THE HAZARDS CONSIDERED

The range of potential hazards associated with feed is broad and possibly increasing with the rising importance of different feed sources and feed production technologies. Many of these hazards are relevant irrespective of the feed source but the local production environment and the specific production processes can be critical in terms of their prevalence.

Chemical hazards

Persistent organic pollutants

POPs are ubiquitous and bioaccumulate in the lipid rich tissues of animals. In particular, the expert meeting considered polychlorinated dibenzo-dioxins (referred to as dioxins from here on), dioxin-like polychlorinated biphenyls (dl-PCBs) and non-dioxin-like polychlorinated biphenyls (ndl-PCBs).

Dioxins are a group of contaminants with common toxicity pathways; the reproductive, immune and endocrine systems are sensitive targets, especially in developing organisms. Thus, dioxins are a priority hazard for feed and food safety.

The ubiquitous presence of dioxins and dl-PCBs in the environment from both natural and anthropogenic sources contributes to their potential presence in feed. Elevated environmental levels have been associated with soil and plant material on flood plains in industrial areas and also with soil and plant material in areas close to sources of industrial emissions. Fishmeal and fish oil produced using fish harvested from contaminated areas can also contain relatively high levels of dioxins. Industrial sources of contamination have included ball clay used as an anticaking agent in feed, lime as a neutralizing agent for citrus pulp, contaminated oils, some mineral sources and most recently contaminated fatty acids. Direct drying of feed, using inappropriate fuel, is another potential source of dioxins. Addressing the food safety risks posed by dioxin and dl-PCBs in feed, requires information on the lipid content of the feed and on the congener profile of these hazards in the feed, which impacts their transfer from feed to food. Dioxin and dl-PCBs s are only slowly eliminated and as such levels found in edible tissues, and milk and eggs, are dependent on the levels in feed and also the duration of exposure.

It is difficult to identify particular adverse effects in humans and animals of ndl-PCBs due to the co-occurrence of the more toxic dioxins and dl-PCBs. Effects on liver, thyroid, reproduction and neurodevelopment have been reported in association with different congeners or congener groups. Work needs to continue internationally to better define the risk associated with these compounds that are generally present at much higher levels in feed than dioxins and dl-PCBs. Ndl-PCBs accumulate in fat, liver, fillets of oily fish and are also transferred to lipid-rich products like milk and eggs. There are differences in the uptake, metabolism, accumulation and excretion as well as toxicity of the different ndl-PCB congeners.

Veterinary drug residues

Feed remains a much-used vehicle for the efficient delivery of veterinary drugs to animals. While transfer, metabolism and toxicity of veterinary drugs in feed to animal products is fully assessed as part of the authorization process and establishment of maximum residue limits (MRLs), the expert meeting noted

3 CAC-GL 45-2003 Available at http://www.codexalimentarius.org/download/standards/10021/CXG_045e.pdf

that this does not cover the different non-target species which may be exposed via cross-contamination of feed, and this may be an important consideration for risk management in some countries.

The issue of veterinary drug residues in feed and food has long been recognized due to long standing concerns for public, animal and environmental health as a result of direct exposure to these residues and concerns that residues of antimicrobials may be associated with the development of antimicrobial resistance.

Organochlorine and other pesticides

Organochlorines are persistent, lipophilic compounds that behave much like dioxins and PCBs and are recognized contaminants of fats (e.g. fish oils) used in feeds. On the other hand, less attention has been paid to the potential of other pesticide groups to contaminate feeds and carry-over to foods of animal origin. Transfer to animal products, metabolism and toxicity of specific pesticides used in plants intended for feed production should be examined prior to pesticide authorization and the establishment of MRLs for feeds and foods of animal origin. The expert meeting noted that existing authorization mechanisms and established MRLs may not always reflect the extent of all plant products that may end up in feed. Additionally, if these plant products are subject to processing, residues may concentrate in by-products that are used as feeds.

Potentially toxic elements (PTEs)

While arsenic, cadmium, lead, mercury, selenium, copper, nickel and chromium are natural components of earth materials, they also have an anthropogenic origin. They can be toxic for animals and transfer to the animal products may occur. For a number of these elements transfer from feed to foods of animal origin tends to be low due to low absorption (e.g. inorganic arsenic, lead) but for others where the half-life is long, e.g. cadmium, significant levels can accumulate, for example in crustaceans. Accumulation of inorganic cadmium in livestock depends on the level and duration of exposure. Methylmercury is a specific, and widely recognized, problem for aquaculture feeds based on fish-derived meals.

Mycotoxins

Mycotoxins contaminate farming systems globally. When ingested in high concentrations through feeds derived from plant material they exert severe toxic effects in animals, may decrease their productivity and may accumulate in edible tissues and animal products,, resulting in human exposure and health effects. Besides Aflatoxin M1 (a carcinogenic agent) in milk and ochratoxin in meat, milk and eggs, the other well-known mycotoxins e.g., zearalenone, fumonisins may seriously affect animal health and productivity, but do not show a major carry-over to foods of animal origin. However, the profile of mycotoxins of importance continues to evolve. There are a range of known toxins that are likely to change in relative importance with evolving agricultural practices, including the use of different feed sources. Moreover, there are likely to be many as yet unrecognized mycotoxins, given that there are many thousands of fungal species, each producing many secondary metabolites that have not been assessed for toxigenicity. This presents an ongoing challenge for monitoring, risk assessment and risk management and in this context the meeting highlighted the importance of mitigating mycotoxin contamination along the feed chain using a range of measures and tools relevant to the local situation. As it is very difficult to remove mycotoxins from contaminated feed, preventing them from accumulating in agricultural commodities is the most effective strategy to combat the problem. Preventive measures range from crop rotation and resistance breeding to inoculation with microbial antagonists and storage management. Continuous monitoring is essential and efficient detoxification strategies are needed to deal with outbreaks and the risks posed by low level exposure.

Plant toxins

Toxin-producing plants may occur in grasslands used in forage and are a significant cause of livestock poisoning. Transfer of some of these toxins to edible products such as eggs, milk and meat has been demonstrated, for example in the case of genotoxic pyrrolizidine alkaloids. Changes in toxin occurrence in plants and concentrations of plant toxins may be caused by climate changes and worldwide an increased occurrence of some toxin producing weeds has been observed which results in a spread of the accompanying risks. Also changes in farming practices from migratory herds to expanded settlement and crop cultivation in dry season grazing land can mean that animals have access to a reduced variety of plants and thus potentially greater exposure to toxic plants. Addressing this means that efforts are

needed to decrease toxicity and anti-nutritional factors in existing and newly available feeds. Given the variety of toxic plants, this presents extensive challenges for risk assessment and further data is needed to accurately characterize this type of hazard and the dose–effect relationship.

Other potential and emerging chemical hazards

A range of contaminants including brominated flame retardants and perflurinated compounds have been shown to be present at low levels in animal feed. However, the expert meeting noted that there is currently insufficient information to assess whether the carry-over via feed of these compounds presents a risk to human and animal health.

Biological hazards

There is a continuous risk for contamination of feed by microbial pathogens throughout the production chain up to feeding to the animals, with the many opportunities for contamination making it difficult to control or fully eliminate specific pathogens. A key aspect of managing this risk is the identification and characterization of pathogens of concern in feed understanding, among other things, the factors that affect the sources, and routes of contamination. *Salmonella* has been identified as an important hazard and a wide spectrum of *Salmonella* serovars have been isolated from feed. This includes those most commonly isolated from clinical cases of human salmonellosis, like Typhimurium and Enteritidis. Other potential bacterial hazards in animal feed to be aware of, according to the feed type include *Mycobacterium*, *Brucella*, *Clostridium* spp, enterohaemorrhagic *Escherichia coli*, and *Listeria*. Parasites in pasture and forage have also been identified as potential hazards. Viruses were also considered and it was noted that in terms of those that are a concern for food safety and human health there is little evidence to date of feed as a source of their transmission to food. However, it was also noted that as feed sources and processing technologies change there is a need to be aware of the impact of these on biological hazards. The lessons learned with the emergence of prions in the not too distant past should not be forgotten. In terms of emerging issues it was also noted that managing environmental diffusion of these hazards will require better knowledge of survival of those organisms under environmental stresses (temperature, irradiation, and desiccation) and climatic changes, which are influencing farm practices, may also present opportunities for increased prevalence and risk from biological hazards.

Physical hazards

Physical hazards, except nanomaterials and radionuclides, do not transfer to animal tissues and as such were not considered in terms of food safety; however, they can have a significant impact on animal health. Considerations are dependent on material, form and particle size as destined for particular animal species, for example, ruminants are not as sensitive to particles as would be chickens and young piglets. However, this is an area where there are some emerging issues, e.g. packaging materials due to use of former food products in animal feed, micro- and nano-plastics in marine environments and therefore the meeting concluded that the relevance of physical hazards in feed for food safety should not be dismissed.

Hazards of feed and products of feed production technologies of increasing relevance

There is an increasing interest, production and use of certain feed ingredients such as insects, former food and food processing by-products, biofuels (bioethanol and biodiesel) by-products, aquatic plants and marine resources. These can present new challenges for risk assessment and management. Concerns revolve around the clear identification and characterization of hazards that may be introduced through incoming materials that are used in processing. In this context a new approach to evaluate the safety of such feed is needed: identifying all incoming material used to produce the feed and their potential hazards, understanding the manufacturing process while identifying potential hazards introduced via processing, and a risk characterization of the final feed product itself. The evaluation of the feed should consider the role of manufacturing processes to mitigate the risk of the hazards. The meet-

ing considered the following feed production technologies and sources that are of increasing relevance:

Insects as feed

To date, there is little information in the public domain about the hazards associated with insects for use in feed and this is an important gap to be addressed for regulatory purposes. Efforts to establish guidance in relation to standardization of insect rearing and processing practices will help to ameliorate risks, acknowledging that production scale and local requirements will have a significant influence on the approach taken.

Food waste and former food products

The worldwide trend for food waste reduction has led to an increase in the recycling and reuse of former food and food processing by-products in the feed chain, which, if not well managed can lead to a greater potential risk of emerging hazards in animal feed. While this can be an important pathway for waste conversion, it is critical from a safety perspective that the feed chain is not used as a means to dispose of degraded or contaminated foodstuffs. Given the diversity of inputs, the range of hazards relevant to feed from these sources could be very broad ranging from heavy metals, pesticides, dioxins and polychlorinated dibenzo-furans, mycotoxins, and residual processing aids, packaging materials, particularly from former food products, and microbial hazards, which can increase particularly in high moisture former food. With the lack of traceability associated with some of these inputs, particularly in the case of post-consumer waste, the expert meeting highlighted that there is potentially an increased risk of animal products being fed back to animals and cycling of hazards in the feed-food chain. The expert meeting noted the need for increased communication between food and feed regulators and industries on the importance of the feed to food continuum and how to limit the diversion of contaminated food products to feed.

Biofuel by products

Biofuel production yields by-products that may be used in livestock feed. These include dried distiller's grains with solubles (DDGS), a high-protein feed from the bioethanol production and the high protein pressed cake and glycerol that remains after oil extraction and processing for biodiesel. A number of hazards have been reported related to these processes including mycotoxins, residual antibiotics and sulphate / sulphite. Also some of the plants cultivated for biodiesel can be toxic to animals. This presents a new challenge in terms of working with an industry outside of the traditional feed/food sector to ensure that the risks associated with these by-products potentially entering the food chain are minimized.

Aquatic plants

Aquatic plants are of increasing interest as feed due to the low inputs required to produce biomass. However these plants also often serve other purposes such as water purification and can take up and concentrate minerals and other potential hazards from their environment. Microbiological hazards may also be a concern due to growth of the plants in waste water. Whether these plants are cultivated or harvested from the wild there is clearly a need for further research.

Marine resources

Algae may be used directly as feed ingredients and as their use as biomass for biofuel production is also envisaged, this might lead to another indirect presence of algal material in feeds, i.e., as biofuel by-products. The expert meeting noted that algae may concentrate many chemical elements, including toxicologically relevant ones (e.g. arsenic, chromium, cadmium, lead) and essential elements that can be toxic at excess doses (e.g. iodine) depending on the algal species, as well as on the medium on which algae are grown, and transfer to food of animal origin will be dependent on a number of factors including ability to bioconcentrate in the consuming species. Another aspect is the potential to unintentionally harvest toxin producing micro algae with algae intended for animal feed in which case algal feed materials can be vectors for accumulated marine toxins. More information is needed about the potential of different algae to accumulate toxic elements, the speciation of such elements when relevant (inorganic vs. organic arsenic) and the influence of environmental conditions, as well as the conditions influencing the accumulation of toxins in algal species and the potential carry-over, if any, of toxins from feed to edible tissues and products.

As fishing activities have a significant output of side-products such as by-catch and fish parts from fish

processing plants these can be hydrolyzed and grained as aquaculture feed. Chemical contamination of these hydrolysates was considered to be comparable to conventional fish feed but increased levels of nano- and micro-plastics may be an issue.

Krill can be a valuable source of aquaculture feed and may lead to lower exposure to conventional hazards associated with aquaculture feed such as mercury. In terms of specific hazards, krill may contain relatively large amounts of fluoride compared to conventional fish feed but if needed the excess fluorine can be addressed by removing the exoskeleton before processing into feed.

RECOMMENDATIONS

In light of the above, the expert meeting recommended:

- FAO and WHO to develop guidelines for the prevention and control of hazards identified in feed to support the efforts of member countries in addressing these hazards;
- FAO, WHO and Member Countries and their capacity development partners to continue with and further enhance capacity development activities, especially on risk assessment and management of hazards in feed, including for feed sources and technologies of increasing relevance, to better meet domestic and international standards.

Need for international standards

- The Codex Committee on Contaminants in Food and the Codex Committee on Food Hygiene to develop and update specific provisions for the control and reduction of chemical and biological contaminants in feed, including decontamination measures, for inclusion in Codex codes of practices for prevention and reduction of food and feed contaminants;
- The Codex Committee on Food Hygiene to address the issues of biological hazards re- entering the food chain through the development of specific guidance on the control of recycled foodstuffs, including food processing by-products and former food, through feed, particularly in the context of the Codex General Principles of Food Hygiene;
- The Codex Alimentarius Commission to revise and update the Codex Code of Practice on Good Animal Feeding to address new hazards derived from the use of feed and feed production technologies of increasing relevance;
- The Codex Committee on Pesticide Residues and Member Countries to establish MRLs for pesticides of concern in feed;
- Member Countries to encourage the Codex Committee on Contaminants in Food to establish MRLs for contaminants of concern in feed.

With regard to feed sources and technologies of increasing relevance to the feed sector:

- FAO, WHO and Member Countries to raise awareness within the food industry, including food retailers, on the importance of maintaining safety standards of former food and/or food processing by-products, when these products are reused as feed;
- The food industry to extend the quality control measures in food processing plants to identify hazards in by products/waste when they will be recycled into feed;
- The food and feed industry to provide information and data on processing aids used during food and feed processing in order to identify any hazards that may be transferred to feed through the use of processing aids;
- FAO and WHO to develop guidelines for the safe production and use of insects as feed;
- FAO and WHO to develop guidelines for the safe production and use of biofuel-by-products as feed;
- FAO and WHO to develop guidelines for the safe production and use of feed from former food products and food processing by products;
- The feed industry, Member Countries, FAO and WHO, possibly in collaboration with the World Organisation for Animal Health (OIE)) to identify hazards in feed and assess their impact on food safety and animal health due to the recycling of animal products e.g. fish by-products back into fish feed, animal fat into feed.

To support risk assessment of hazards in animal feed:

- FAO and WHO to collect, through the extension of the Global Environment Monitoring System (GEMS/food), monitoring data regarding the occurrence in feed of the hazards described in this report;
- Member Countries, FAO and WHO to encourage regulators to require relevant data packages from industry to support the risk assessment of pesticides residues in feed. Consider pesticide residues in feed especially as they pertain to feed ingredients, including byproducts used as feed, which may not have been previously assessed;
- FAO, WHO and the Codex Committee on Residues of Veterinary Drugs in Food to consider the risk from the residues of veterinary drugs resulting from cross-contamination from medicated to non medicated feed in international risk assessment and where necessary develop the appropriate risk management measures;
- The Organisation for Economic Co-operation and Development (OECD) and FAO to identify specific considerations relevant to the assessment of feed and feed production technologies of increasing relevance and where relevant update existing guidance and tools which would facilitate international harmonization in this area;
- FAO and WHO to develop guidelines for appropriate sampling of feed recognizing that hazards in feed are not always homogeneously distributed;
- Member Countries to develop risk-based approaches/procedures and sampling plans for data collection and monitoring of hazards in feed.

Research needs

- The scientific community and Member Countries to carry out further research to identify, characterize and prioritize potential hazards from environmental pollutants, and determine their occurrence in feed;
- The scientific community to carry out research and WHO and FAO to develop methods/guidelines for risk assessment on the combined effects on human and animal health of multiple hazards of particular relevance to feed;
- The scientific community and Member Countries to carry out further research to identify, characterize and prioritize plant toxins, with particular attention to the development of analytical methods, and determine their occurrence in feed;
- The scientific community and the industry assess hazards in raw materials and other substances used for production of biofuel when by-products are diverted to feed;
- The scientific community to carry out research to improve the identification and characterization of hazards in feed sources of increasing relevance such as insects and aquatic plants and marine products and resources;
- The scientific community to carry out scientific research and FAO and WHO promote a harmonized approach for risk assessment of hazards associated with nanomaterials in feed and nanoparticles present in the environment, which may contaminate feed. This includes the development of analytical methods for the determination and characterization of nanoparticles in feed.

Future work be undertaken

- Because of the short duration of the expert meeting, many important issues that were within its scope could not be considered in detail. Continued discussion is required at an international level to allow addressing more compressively the following:
- Hazards in feed that are of particular concern for animal health and productivity, taking into consideration the need to ensure food security;
- Other risks to human health, such as occupational health issues, and when feasible their inclusion in feed risk assessment.